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Stock Market Interdependence: Evidence from Australia

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STOCK MARKET INTERDEPENDENCE: EVIDENCE FROM AUSTRALIA

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Abstract

This study examines the relationship between Australia's stock market and the five largest international markets for the period 1991 through 2001. Preliminary findings, using correlation statistics, indicated potential benefits to international diversification for the Australian investor. Further analysis, conducted in the VAR framework using the Johansen co-integration method, found that the Australian market has short and long run linkages with the United States, while tests with other markets found little evidence of interdependence. Moreover, only the US market was found to Granger-cause the Australian market.

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I. INTRODUCTION

Investigating relationships between international stock markets has received much academic and practitioner interest over the last 30 years. The study of market interdependence holds important implications for the theory of financial economics, in particular, the degree to which markets are integrated determines the benefits from diversification of investment portfolios.

International diversification of stock portfolios has long been advocated by the financial economics literature[1]. Investment in less than perfectly positively correlated national capital markets provides gains to the investor, predominantly due to a reduction of overall systematic risk. However, various investment barriers (restrictions on capital movements, undeveloped capital markets) have, historically, made it difficult to fully exploit diversification opportunities for investors.

One of the defining characteristics of financial market development over the past decade has been the emergence of a pronounced globalisation trend. Globalisation of financial markets has seen most investment barriers diminished, thereby heightening

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[1] See, for example, Grubel (1968), Levy and Sarnat (1970) and Solnik (1974).

the opportunities to engage in international diversification. While the diversification opportunities have become more prevalent, evidence shows that fund managers around the world hold a substantial portion of the assets in domestic financial assets.[2] The bias toward domestic investments, or 'home country bias', is particularly pronounced in Australia. The average Australian pension or 'superannuation' fund has 40% of assets allocated to domestic equities, with around 20% allocated to international equities[3]. This high concentration of domestic equities is prevalent despite the Australian market accounting for less than 2% of world stock market capitalisation[4]. Two issues result from this finding: first, the average superannuation investor has a strong under-diversification bias; and, second, the large proportion of fund assets allocated to Australian equities has resulted in superannuation funds dominating more than 70% of domestic stock market value.

Against this institutional setting, it is timely to investigate the interdependence of the Australian stock market with the major markets around the world. The aim of this study is to provide positive insights into the linkages between Australian and international stock markets to evaluate the benefits of international diversification for superannuation funds. The rest of the paper is organised as follows. Section II considers previous research in the field of interdependence, with special reference to Australia. Section III describes the data and considers the tests of interdependence employed in this study, commencing with simple static correlation measures, moving to vector autoregression (VAR) and cointegration methodologies to examine short and long run linkages between markets. Section IV provides concluding remarks.

II. LITERATURE REVIEW

Renewed interest in the interdependence debate was the result of advances in cointegration analysis over the late 1980s and the early 1990s. The cointegration technique bridged the gap between short-run dynamics and the long-run equilibrium relationship of financial time series by allowing an error-correction mechanism to bring the series towards its equilibrium. Many studies in the early 1990s examined the impact of specific events on the interdependence of stock markets using cointegration analysis. The review commences with a discussion of this event-specific research, concluding with a detailed discussion of recent contributions made on the interdependence of Australian and international markets.

Taylor and Tonks (1989) hypothesised that the abolition of exchange controls in 1979 in the United Kingdom (UK) had altered the relationship of its stock market with the rest of the world. A sample of monthly price indices from the UK, the United States (US), Japan, (the then) West Germany and the Netherlands were collected from 1973 through 1986. Using single-equation cointegration techniques, Taylor and Tonks

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[2] The fact that investors do not generally hold the world market portfolio suggested some inherent bias that has caused the theoretical gains of international diversification to be foregone. This evidence would suggest that mean and variance were still not the only considerations in the formulation of the optimal asset allocation mix. The home bias has been recognised in many other studies, and research was conducted to find an economic explanation for the phenomenon. Variables affecting international investment were evaluated and they ranged from observable factors such as transactions cost (Tesar and Werner, 1995) and inflation hedging (Cooper and Kaplanis, 1994) to non-observable factors such as non-traded goods (Baxter and Jermann, 1997), behavioural factors (French and Poterba, 1991) and information asymmetry (Kang and Stulz, 1996).

[3] As at June 2001. Figures from APRA Superannuation Trends June Quarter 2001.

[4] June 2001 estimates from Morgan Stanley Capital International (MSCI).

(1989) reported that the changes in the coefficients were insignificant. However, the cointegration analysis suggested that the UK was cointegrated with some foreign markets after 1979.

Ma (1993) criticised the conclusions of Taylor and Tonks (1989), because its implications would mean that UK exchange controls had prevented non-UK markets from being integrated. One would expect that other markets without exchange controls should have been cointegrated prior to 1979. Using the Johansen (1988) procedure, Ma (1993) demonstrated that the UK market was cointegrated with the four other markets before and after 1979, and cautioned that the results provided by Taylor and Tonks (1989) were due to underspecification of the cointegrating regression.

Kanas (1998) used cointegration analysis to examine the relationship of the stock market indices of the six largest European markets surrounding the 1987 stock market crash. In contrast to the previous studies that had used static techniques, no significant linkages between these markets were found. In a subsequent study, Kanas (1999) had different results using comparable MSCI country indices of the UK and U.S. markets. There was no cointegration before 1987 but the markets were significantly linked after 1987. Kanas (1999) did not explicitly reconcile the contrasting results in both studies, but noted that the use of MSCI indices overcame the problem of technical construction differences as suggested by Roll (1992).

While developments in the econometrics field permitted researchers to examine the cointegration of international stock markets, economic theory required an underlying trend that linked international markets to a long run relationship. While specific criticism can be directed at the previously discussed cointegration studies, a general criticism is that insufficient efforts were made to identify trend(s) and link these to theory.

This problem motivated Kasa (1992) to test for common trends in international stock markets[5]. Kasa (1992) tested for common trends using the Johansen procedure. Monthly and quarterly MSCI indices from the Canada, Japan, Germany, UK and US from 1974 through 1990 were converted into real USD terms. Cointegration test results indicated a single common stochastic trend affected the long run co-movement of all markets. Estimates of factor loadings suggested that this trend was most important in the Japanese market and of least importance to Canada. Similar to the findings in Taylor and Tonks (1989), the results implied that the gains to international diversification were overstated for long holding periods. However, Kasa (1992) noted that the stochastic trend had different properties from the price trend, making it difficult to identify.

The pioneering work of Kasa (1992) relating to common trends in markets has been subjected to scrutiny and criticism from subsequent studies. In particular, Richards (1995) argued that the presence of a single stochastic trend was achieved by over-

[5] The research of Kasa (1992) posed three important questions: First, if prices in each individual country's stock market have a random walk with drift component, are these random walk components different, or do they arise from the response of each country to a single, common world growth factor?; second, how many common trends are there in the equity markets of the major countries?; and, finally, do these trends reflect the economic integration of global markets, or are markets statistically cointegrated for some other reasons not relating to some underlying economic theory?

parameterising the models used in the cointegration analysis. Kasa (1992) claimed that long lag structures were used to capture the possible effect of mean reversion in stock prices. However, this resulted in the equation having 51 explanatory variables and only 57 observations. Richards (1995) found no strong evidence of cointegration between 16 MSCI country indices from 1969 through 1994, indicating stock markets behaved differently over the long run.

Engsted and Lund (1997) re-examined Kasa's (1992) study, and specified a single VAR model that encompassed dividend effects with price changes. The results indicated that dividend yields were cointegrated across countries. Therefore, stock prices would be cointegrated if the underlying fundamentals determining stock prices were cointegrated. Geographical proximity and international trade agreements (or 'investment unions') had been cited as two potential explanations as to why markets shared common trends.

In a study of the Pacific-Basin stock markets of Australia, Hong Kong, Japan, New Zealand and Singapore over a 20 year observation period, Corhay, Rad, and Urbain (1995) found evidence of cointegration. However, a detailed analysis uncovered some regional aspects (Asian versus Pacific) in the relationship. The recent study by Masih and Masih (1999) provided corroborating evidence of geographical proximity explaining the cointegration of Asia's emerging markets.

The role of investment unions in cointegration was first explored by Lessard (1973). A recent study by Cheung and Lai (1999) supported the investment union hypothesis, using a sample of countries in the European Monetary System from 1979 through 1992. Moreover, the results suggested two permanent components were driving prices in these markets. Cheung and Lai (1999) considered macroeconomic factors such as money supply, industrial production and dividends, however, none of these factors produced conclusive results. The contribution of Cheung and Lai (1999) highlights the difficulty of using observable economic variables to explain cointegration.

Francis and Leachman (1998) theorised an alternative interpretation of cointegration between national stock markets. Contrary to Richards (1995), it was argued that the error-correction mechanism in cointegrated systems could have arisen because investors form (near) rational expectations. This proposition was particular relevant for international asset pricing models that were based on homogenous investor expectations. Francis and Leachman (1998) found positive cointegration results from the German, Japanese, UK and US markets through tests of superexogeneity. Tests of the composite characteristic superexogeneity in these markets was designed to determine the extent to which stock prices represent the present discounted value of expected future dividends. The test results rejected superexogeneity for Japan and the UK. The results suggested that the Japanese market was rather isolated and invariant to events over the observation period.

Turning to the evidence from Australia, a major study by Allen and MacDonald (1995) examined the relationship of stock indices from 16 countries from 1971 through 1992 to determine the diversification benefits for Australian investors. Cointegration tests on pairwise combinations of the domestic and international markets found that Australia was cointegrated with Canada, France, Germany, Hong

Kong, Switzerland and the UK. Although this would imply that long run diversification benefits still exist for the other markets, Allen and MacDonald (1995) conceded that it was difficult to provide explanations for why some of these markets were cointegrated. Allen and MacDonald (1995) extended their bivariate analysis to the multivariate setting by considering 3 simply constructed portfolios. Together with Australia, Portfolio A consisted of the Japan, the US and 3 other major markets; Portfolio B was made up of Japan, UK and US; and, Portfolio C contained the Canada, UK, and US markets. The multivariate results indicated that Portfolios B and C were cointegrated, but the results were sensitive to the bivariate relationships established earlier. If the UK market was added to the bivariate system of Australia and the U.S., the test would have indicated a cointegrated trivariate system.

Roca (1999) and Roca and Selvanathan (2001) studied the interdependence of the Australian market and various major and other Asian markets. Roca (1999) observed that trade between Australia and Hong Kong, Korea, Singapore and Taiwan, had grown substantially over the years. Therefore, it was hypothesised that Australia would be more economically integrated with these Asian countries, leading to the expectation that the financial markets of these countries were interdependent.

Roca (1999) investigated a sample of weekly MSCI country indices for Australia, Hong Kong, Singapore, UK and US from 1975 through 1995. Data for Korea and Taiwan commenced in 1988. The sample was split into sub-periods to take account of the financial deregulation in Australia in 1983 and the 1987 stock market crash. Roca (1999) did not reject the hypothesis that the Australian market was not significantly cointegrated with any of the markets in the long run. However, significant short-run relationships were found with the UK and the US. Roca and Selvanathan (2001) reported no cointegration in the short or long run between Australia and the Asian countries of Hong Kong, Singapore and Taiwan.

The contributions of Allen and MacDonald (1995), Roca (1999) and Roca and Selvanathan generally found little evidence of long-term linkages between markets, thereby suggesting long-term diversification benefits to the Australian investor. While previous studies have largely focussed on the Australian market's interdependence with markets of close geographical proximity, this study is particularly concerned with the largest international stock markets using a post-crash sample. The observation period for this study commenced in 1991 (with the announcement of the Superannuation Guarantee Levy) through to aftermath of the dot.com bubble in 2001. Anecdotal evidence suggests the interdependence of stock markets internationally has heightened over this period, which will provide stronger empirical evidence of the extent to which markets are related.

III. ANALYSIS

This study considers the issue of interdependence from the perspective of an Australian investor. The international markets selected were those of France, Germany, Japan, UK and US. These 5 countries belong to the G-7 wealthiest states, with their respective stock markets accounting for 75 percent of world market capitalisation. The dominance of these countries is of interest, as exposure to these markets would feature prominently if the international component of a superannuation fund was allocated according to classical portfolio diversification theory.

A. Correlation Analysis

Listed in Table I are descriptive statistics of weekly real AUD returns (calculated by taking the first log difference of each series) of MSCI country indices from 4 January 1991 through 29 June 2001. The international market data is leptokurtic, with too many large changes in the returns to be consistent with a normal distribution. This property can also been observed in the extreme values of the series, where the foreign market returns have higher absolute extreme values than the Australian market.

TABLE I

Summary Statistics for Weekly Equity Market Returns

	Australia	France	Germany	Japan	UK	US
Mean	0.14%	0.21%	0.18%	0.01%	0.16%	0.28%
Maximum	6.14%	11.81%	9.44%	12.09%	10.38%	7.91%
Minimum	-5.19%	-7.45%	-13.06%	-10.48%	-6.08%	-9.80%
Std. Dev.	1.84%	2.60%	2.78%	3.20%	2.24%	2.35%
Skewness	0.1018	0.2028	-0.2199	0.3462	0.1127	-0.1286
Excess Kurtosis	0.3371	0.7543	1.3158	0.8618	0.7453	1.2918
Jacque-Bera	3.5145	16.7203	43.8665	27.8547	13.9155	39.5403
p-value	0.1708	0.0002	0.0000	0.0000	0.0010	0.0000
Obs.	547	547	547	547	547	547

An important feature of the stock price data is the contemporaneous correlation between weekly changes in the various markets. Correlations for the entire sample period are displayed in Table II. It was found that returns in the Australian market were not strongly correlated with the major foreign markets. The Western European markets of France, Germany and UK had returns that were strongly correlated (with the EMS countries of France and Germany showing the greatest correlation). These markets were also strongly correlated with the US. The correlation coefficients of Japan suggested that the market had a relatively weak relationship with the other international stock markets.

TABLE II

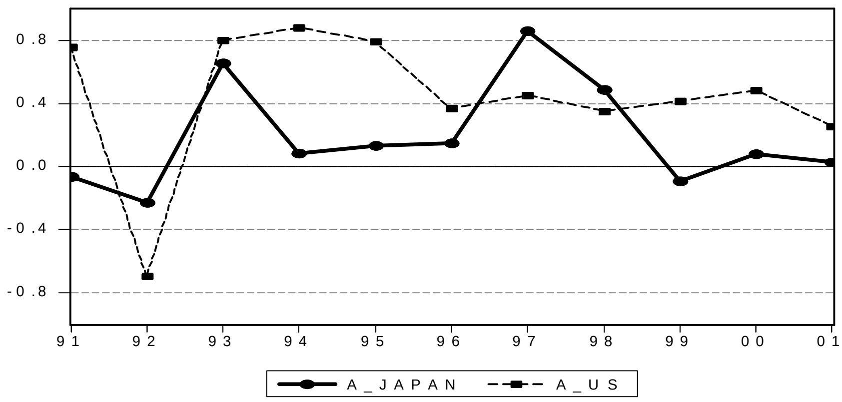
Contemporaneous Correlation between Weekly Returns (real AUD terms)

	Australia	France	Germany	Japan	U.K.	U.S.
Australia	1	0.266	0.279	0.199	0.300	0.313
France		1	0.740	0.334	0.659	0.582
Germany			1	0.275	0.606	0.533
Japan				1	0.325	0.258
U.K.					1	0.562
U.S.						1

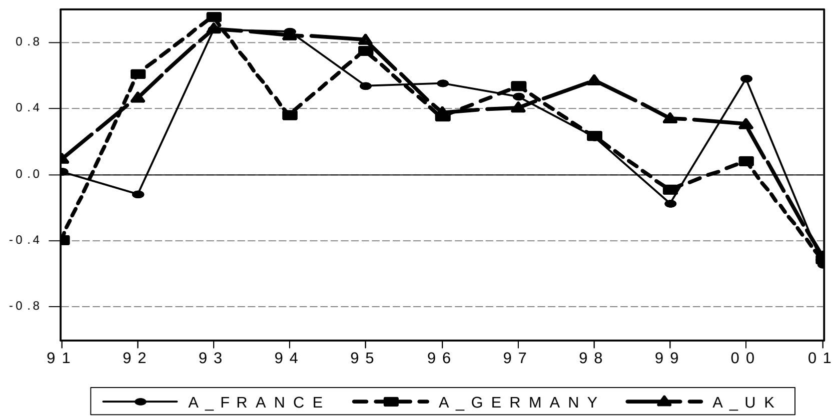
While the coefficients shown in Table II provide some preliminary insight into the interdependence of markets, it must be noted that these are static measures and, as such, do not reflect the dynamic relationships between markets. Correlations between countries have been shown to be time varying (Longin and Solnik, 1995). To illustrate this dynamic behaviour, the correlation coefficients are decomposed into annual estimates measuring only the correlation of the foreign markets with the Australia market[6]. These correlations are plotted in Figure I.

FIGURE I
Annual Correlation of Weekly Returns, 1991 to 2001

Panel A: Australia with US and Japan



Panel B: Australia with Western European Markets



The correlation coefficients can be seen to vary every year in Figure I, with the overall trend of positively correlated returns throughout the sample. As the correlation between the Australian and international markets is less than unity, domestic investors will benefit from holding an internationally diversified portfolio.

B. Unit Root Tests

The order of integration of each series was determined using the unit root tests of Dickey and Fuller (Augmented-DF) (1979) and Phillips and Perron (1988). Lag lengths of the ADF test were determined by minimising the Akaike (1974) and Schwartz (1978) information criteria. The Phillips-Perron tests used the Newey-West correction based on a truncated correlation structure of 5 lags. The coefficients for the deterministic regressors have been restricted to be zero in the test equations. The

[6] A common practice in depicting time-varying correlations is to construct rolling correlations of the returns. However, due to the moving average component and overlapping observations by construction, the line plots would be rather difficult to interpret statistically. Therefore, it was deemed that a simple decomposition of the correlations into sub-periods was more meaningful.

stock indices are tested in the price levels for unit roots, and subsequently, the first difference of the stock indices are tested for unit roots.

TABLE III

Unit Root Test Results for Weekly Series

$$\Delta Y_{it} = a_0 + r_0 Y_{it-1} + \sum_{i=1}^{p} r_i \Delta Y_{it-1} + e_{it}$$

where: Y_{it} denotes the index for the *i*-th country at time *t*;
$Y_{it} = Y_t - Y_{it-1}$, ? are coefficients to be estimated;
p is the number of lagged terms;
a_0 is the constant; and,
e is white noise.

	ADF Test Statistics		PP Test Statistics	
	H_0: Unit root against H_1: No unit root			
	Levels	First Diff.	Levels	First Diff.
Australia	-2.1288	**-25.0208	-2.4799	**-24.9967
Japan	-2.3069	** -9.3365	-2.2195	**-26.3692
France	-0.5844	**-13.7219	-0.5893	**-24.5122
Germany	-0.7829	**-14.0928	-0.7793	**-25.4435
United Kingdom	-0.8892	**-17.6959	-0.8373	**-25.2822
United States	-0.6227	**-13.6550	-0.6821	**-27.5991
1% Critical Value[1]	-3.4447			
5% Critical Value	-2.8671			
10% Critical Value	-2.5697			

[1] MacKinnon (1991) critical values.
* Significant at the 5% level critical value
** Significant at the 1% level critical value

The unit root tests of the indices in the levels listed in Table III produced test statistics that were not significant, indicating the levels of all the indices have unit roots. The tests of the first differences of the indices produced test statistics that were significant at the 1% critical value, rejecting the null hypothesis of a unit root. Therefore, taking the first difference would render the indices stationary. From the unit root test results, all the stock indices are found to be integrated of order one, that is, *I*(1) process, thereby allowing them to be used in cointegration and VAR tests of long-run relationships between stock markets.[7]

C. Bivariate Cointegration Analysis

The relationship between Australian and international markets is initially investigated using bivariate techniques. Therefore, there will be five different pairings, and, consequently, five VAR models. In its mathematical form, the VAR is expressed as:

$$y_t = A_1 y_{t-1} + \ldots + A_p y_{t-p} + Bx_t + e_t \tag{1}$$

where:

y_t is a *k*-vector of endogenous variables;

[7] Using daily and monthly data, the ADF tests produced similar conclusions to the tests with the weekly dataset, suggesting that the ADF test used was insensitive to the sampling interval. Another noteworthy observation is that the first differences of the daily data produced the lowest test statistics, giving a stronger rejection of the null hypothesis than the tests with data at longer intervals.

x_t is a d vector of deterministic or exogenous variables;
$A_1, \ldots, A_p$ and B are matrices of coefficients to be estimated; and,
e_t is a vector of innovations that may be contemporaneously correlated with each other but are uncorrelated with their own lagged values and uncorrelated with all the right-hand side variables.

The first step in the bivariate analysis was to determine the optimal lag length for each VAR model. The lag structure of the VAR model was chosen by the sequential likelihood ratio test on the differenced series of the form. Ten lags were specified in the general VAR model and sequentially tested down the specific model. The optimal lag length corresponds to the lag when the null hypothesis is not rejected. The LR tests results (Appendix A) indicated a lag length of two for the Germany pairing and one for the other pairings. This is intuitively consistent with the expectation that equity markets would not have strong serial correlation beyond a horizon of one week. In addition, a low optimal lag length circumvents the Cheung and Lai (1993) findings that the Johansen tests are biased toward finding cointegration more often than what asymptotic theory had suggested (finite-sample bias) as the lag length increases.

With the identification of the optimal lag lengths of the VAR models completed, the Johansen cointegration test was used to obtain the cointegration rank. The coefficient for the deterministic trend in the data was restricted to be zero. An intercept and no trend was specified for the cointegrating equation. Eigenvalues and the corresponding trace and maximum-eigenvalue statistics are detailed in Table IV for the various null and alternative hypotheses for the pairwise combination of markets.

TABLE IV

Bivariate Cointegration Tests Results

H_0	H_1	Eigenvalue	Trace Statistic	Max-Eigenvalue Statistic
Panel A: Australia and France				
$r = 0$	$r > 0$	0.0225	16.5396	12.3753
$r = 1$	$r > 1$	0.0076	4.1643	4.1643
Panel B: Australia and Germany				
$r = 0$	$r > 0$	0.028	19.4927	15.4439
$r = 1$	$r > 1$	0.0074	4.0488	4.0488
Panel C: Australia and Japan				
$r = 0$	$r > 0$	0.0137	11.8448	7.4945
$r = 1$	$r > 1$	0.008	4.3503	4.3503
Panel D: Australia and UK				
$r = 0$	$r > 0$	0.0288	18.3049	15.923
$r = 1$	$r > 1$	0.0044	2.381	2.371
Panel E: Australia and US				
$r = 0$	$r > 0$	0.0398	**27.3600	**22.1313
$r = 1$	$r > 1$	0.0095	5.2287	5.2287

		Critical Values for Trace Statistic		Critical Values for Max-Eigenvalue Statistic	
H_0	H_1	5%	1%	5%	1%
$r = 0$	$r > 0$	19.96	24.6	15.67	20.2
$r = 1$	$r > 1$	9.24	12.97	9.24	12.97

Critical Values are taken from Osterwald-Lenum (1992).

* Significant at the 5% level critical value

** Significant at the 1% level critical value

The cointegration results listed in Table V fail to reject the null hypotheses of no cointegration in the pairings of Australia with France, Germany, Japan and the UK. On the other hand, both the trace and maximum-eigenvalue statistics were rejected at the 1% critical value for the pairing of Australia and the US. The results suggest that significant long-run price linkages exist between the Australia and US market, with these two countries sharing a common stochastic trend.

Diagnostic tests were undertaken to check the ‘whiteness’ of the residuals. The critical values of the Johansen cointegration tests obtained previously are made under the assumption of normal innovations. Therefore, deviations from Gaussian properties would adversely affect the results of the tests.

TABLE V
Residual Tests for Bivariate VAR Models (*p*-value in parentheses)

VAR in First Differences								VECM	
Australia & France		Australia & Germany		Australia & Japan		Australia & UK		Australia & US	
1		2		1		1		1	
2654.986		2614.277		2526.96		2737.419		2728.812	
		Panel A: Serial Correlation LM Test H_0: No serial correlation at 2 lags							
7.0022		1.2284		0.8844		3.4411		5.0702	
(0.1358)		(0.8734)		(0.9268)		(0.4869)		(0.2802)	
		Panel B: Normality Test H_0: Residuals are multivariate normal							
9.2728		31.1478		47.3325		6.2333		39.2386	
(0.0546)		(0.0000)		(0.0000)		(0.1824)		(0.0000)	
		Panel C: Heteroskedasticity Test H_0: No heteroskedasticity							
15		42		15		15		60	
7.2924		76.5883		18.7002		18.5638		90.6474	
(0.9490)		(0.0009)		(0.2276)		(0.2342)		(0.0065)	
		Panel D: Univariate ARCH LM Test H_0: No ARCH effects at 2 lags							
AU	FR	AU	GR	AU	JP	AU	UK	AU	US
1.3907	4.5031	3.3720	15.4063	5.7390	11.6022	6.4597	5.6796	4.0895	25.2020
(0.4988)	(0.1052)	(0.6428)	(0.0087)	(0.3324)	(0.0406)	(0.2640)	(0.3386)	(0.5366)	(0.0001)

LM tests for serial correlation do not indicate its presence in the residuals for all models, suggesting that the lag length had captured any serial correlation sufficiently. Earlier, the descriptive statistics for the weekly returns indicated only the Australia returns were normally distributed. In the bivariate models, some non-normality was evident in the pairings with Germany, Japan and US. However, Cheung and Lai (1993) report that Johansen tests were reasonably robust to non-normality[8].

D. Multivariate Cointegration Analysis

The cointegration analysis is extended to a multivariate setting, where the six indices are specified into a VAR in order to investigate any evidence of a single-market notion. The optimal lag length was tested in the same manner as the bivariate analysis. Likelihood ratio test results indicated an optimal lag structure of 1 lag, which again is consistent with the expectation that the dynamics between equity markets do not extend beyond a week.

[8] The trace test was more robust to skewness and kurtosis than the max-eigenvalue test through Monte Carlo simulations of non-normal innovations. The univariate ARCH LM tests reported its presence for both Germany and the US. Conditional heteroskedasticity is a commonly known source of leptokurtic innovations. Lee and Tse (1996) extended the Cheung and Lai (1993) analysis by examining the power of the Johansen tests when the residuals followed a GARCH (1,1) process and found that similar finite-sample bias exist, but was deemed not to be serious.

Similar to the bivariate analysis, the coefficient for the trend in the price level is restricted to zero, with an intercept and no trend in the cointegrating equation. The multivariate cointegration test is conducted with the null hypothesis of no cointegration considered against the alternative of at least one cointegrating relationship. This is followed by the null hypothesis of one cointegrating relationship against the alternative of at least two cointegrating relationships, and so forth. The trace and maximum-eigenvalue statistics are again used to test the hypotheses at the 5% critical value. The results are presented in Table VI.

TABLE VI

Six-country Multivariate Cointegration Test with Weekly Data

H_0	H_1	Eigenvalue	Trace Statistic	5% Critical Value	Max. Eigenvalue Statistic	5% Critical Value
r = 0	r > 0	0.0706	100.6752	102.14	39.9957	40.30
R = 1	*r* > 1	0.0416	60.6796	76.07	23.2005	34.40
R = 2	*r* > 2	0.0254	37.4908	53.12	14.0453	28.14
R = 3	*r* > 3	0.0234	23.4337	34.91	12.9532	22.00
R = 4	*r* > 4	0.0137	10.4805	19.96	7.5195	15.67
R = 5	*r* = 5	0.0054	2.9611	9.24	2.9611	9.24

Critical Values are taken from Osterwald-Lenum (1992).

* Significant at the 5% level critical value

The multivariate cointegration results indicated no cointegrating relationships in the system of 6 markets, meaning the markets did not share any common trends in the sample period. This would then require the multivariate system to be expressed in first difference form. As with the bivariate analysis, diagnostic tests are required to check the whiteness of the residuals and the results are presented in Table VII. Serial correlation has again indicated that the optimal lag structure has captured any serial correlation sufficiently. Non-normality and heteroskedasticity are statistically significant, leading to the reported ARCH effects in the German (1%), Japan and US (5%) returns, which were similar to the diagnostics for the bivariate VAR models.

TABLE VII

Residual Tests for Multivariate VAR Model (*p*-value in parentheses)

Panel A: VAR in First Differences	
Optimal Lag Length	1
Log-Likelihood	8137.924
Panel B: Serial Correlation LM Test	
H_0: No serial correlation at 2 lags	
Df	36
LM Statistic	45.4704
	(0.1339)
Panel C: Normality Test	
H_0: Residuals are multivariate normal	
Df	12
Jacque-Bera Statistic	238.4327
	(0.0000)
Panel D: Heteroskedasticity Test	
H_0: No heteroskedasticity	
Df	567
White Statistic	675.3812
	(0.0011)
Panel E: Univariate ARCH LM Tests	
H_0: No ARCH effects at 2 lags	
Australia	0.7095
	(0.7013)
France	4.9493
	(0.0849)
Germany	19.6785
	(0.00005)
Japan	6.4140
	(0.0404)
UK	0.4652
	(0.4951)
US	6.4171
	(0.0404)

In addition to the residual tests used to validate the results of the VAR analysis, this study attempted to explore the effects of varying the specifications of the Johansen tests on the final results. Several tests are estimated with and without deterministic components and the intercept in the data and cointegrating equations.[9]. The results are presented in Appendix II. In general, the inclusion of deterministic trends

[9] There are numerous alternatives ways to investigate the sensitivity of the cointegration tests. One could estimate the test using higher lag orders and compare the results. Gonzalo and Lee (1998) recommended using both the Engle and Granger (1987) and Johansen tests and compare the results from both tests. This can be found in Allen and MacDonald (1995). The investigation in this study is limited to variations of the Johansen tests.

produced trace and max-eigenvalue statistics that gave conflicting results to the cointegration tests[10].

Summarising the cointegration test results, only the Australia/US pairing was found to have a significant long-run relationship, whereas the pairings with France, Germany, Japan, UK and the 6-market system, failed to find any common trends. The residual tests indicated the presence of ARCH effects for the German and US indices, resulting from the presence of non-normality and heteroskedasticity of the residuals. However, Lee and Tse (1996) argue that this problem was generally not serious for researchers. Finally, it was found that the Johansen tests were relatively insensitive to the presence of deterministic trends.

F. Granger Causality Tests

As no cointegration was found for pairings (with the exception of the US), further analysis is limited to the multivariate model to investigate short run causal relationships. Pairwise Granger (1969) Causality tests are carried out to test whether an endogenous variable (a given country's stock returns) can be treated as exogenous.

Table VIII lists Wald statistics for the joint significance of the variables in the 6 equations in the multivariate VAR. A significant Wald statistic means that the foreign market return Granger-causes the dependent market's return.

[10] Similar to the ADF tests, the effects of varying the sampling intervals are investigated by using daily (at 5 lags) and monthly (at 1 lag) datasets in the cointegration tests. While monthly data tests produced similar conclusions on the Australia-U.S. linkage, daily data tests found evidence of cointegration in the pairings of Australia and Germany, the U.K. and the U.S. The disparity of the test statistics indicated that the Johansen cointegration test was prone to sample interval distortions.

TABLE VIII

VAR Pairwise Granger Causality Tests/Block Exogeneity Wald Test

Panel A: Australia				Panel D: Japan			
Exclude	Chi-sq	*df*	Prob.	Exclude	Chi-sq	*df*	Prob.
France	2.3649	1	0.1241	Australia	0.1736	1	0.677
Germany	0.0085	1	0.9264	France	0.1658	1	0.6839
Japan	0.1619	1	0.6874	Germany	0.2303	1	0.6313
UK	0.0050	1	0.9438	UK	3.0548	1	0.0805
US	4.5970	1	0.032	US	3.5776	1	0.0586
All	21.4851	5	0.0007	All	11.0595	5	0.0502
Panel B: France				Panel E: UK			
Australia	0.1001	1	0.7517	Australia	0.5946	1	0.4406
Germany	1.0837	1	0.2979	France	5.4717	1	0.0193
Japan	0.1234	1	0.7254	Germany	2.4599	1	0.1168
UK	0.5193	1	0.4711	Japan	2.4894	1	0.1146
US	0.6463	1	0.4214	US	1.6045	1	0.2053
All	2.4551	5	0.7832	All	10.6623	5	0.0585
				8hj			
Panel C: Germany				Panel F: US			
Australia	0.6606	1	0.4163	Australia	1.7754	1	0.1827
France	6.7018	1	0.0096	France	0.5356	1	0.4642
Japan	0.0091	1	0.9241	Germany	0.1065	1	0.7441
UK	0.3980	1	0.5281	Japan	0.0242	1	0.8764
US	0.0273	1	0.8687	UK	2.1905	1	0.1389
All	10.2091	5	0.0695	All	5.6538	5	0.3414

The Wald statistics reported in Table XI suggest that there is little feedback between the pairwise combinations. The US market was found to Granger-cause the Australian and Japanese markets only, despite the size of its economy and market. In Europe, the French market has causal effects on the German and UK markets, but no market Granger-causes the French market. Similar findings were found for the US market, where the market had no significant causal inflows. The joint significance test suggested that altogether, the 6 markets Granger-causes the Australian, German, UK and Japanese markets. From Australia's perspective, the causal flows from the US underline the long-term linkages that exist between the two markets.

IV. CONCLUSION

This study has found that international equity returns have generally outperformed the Australia market on a risk-adjusted basis over the observation period. More importantly, Australian equity returns are less than perfectly correlated with major international markets, suggesting gains to international diversification. Each of the six indices investigated followed a non-stationary $I(1)$ process, with only the Australian and the US markets sharing a common stochastic trend. Finally, only the US market was found to Granger-cause the Australian market.

The cointegration results reported were not consistent with the Australian study of Allen and MacDonald (1995), but had some commonality to Roca (1999) and Roca and Selvanathan (2001). Allen and MacDonald (1995) found significant long-term linkages with France, Germany and UK and none with Japan and US stock markets. In a multivariate test, Roca (1999) found that the Australia, Hong Kong, Singapore, the UK and US markets were not cointegrated. Both of these studies used data spanning from the 1970s to the mid-1990s. The sample period used in this study was able to capture the performances of the various markets post the 1987 stock market crash, commencing with the introduction of the Superannuation Guarantee Levy in 1991. The period also encompassed the technology sector boom, and its subsequent meltdown from 2000.

With this last point in mind, the lack of long run interdependence between Australia and the markets of the other industralised countries (apart from the US) could be due to the diversity of the industrial structure, lending support to Roll's (1992) argument. The technology stock bubble provides a good illustration of this argument. The Australian market had generally under-performed the other markets (except Japan) in terms of real risk-adjusted AUD returns from 1995 through 1999, predominantly due to the technology-led bull market internationally. More importantly for the diversification argument, the subsequent meltdown in the technology sector internationally saw the Australian market recording higher risk-adjusted returns in 2000 compared with its international peers. As a result, Australia's correlation with the countries examined in this study was relatively low.

For asset allocation purposes, the US remains an attractive area for investment because of its size and market structure. For the major European countries, diversification provides substantial benefits for Australian investors. However, correlation analysis conducted by Cheung and Lai (1999) suggests that the markets in EMS countries are highly correlated and cointegrated. Investors should view the European market as a single entity in light of the region's efforts to achieve economic and monetary union. Finally, the Japanese market appears to provide benefits through diversification, but its return performance over the decade was not encouraging. A full recovery from its fundamental problems would perhaps see the Japanese stock market become more integrated with the rest of the world's major markets.

Overall, the results have suggested that some segmentation still exists in the global market. This has important implications for Australia's superannuation fund industry when formulating long-term global investment strategies. With only a single significant long-term relationship indicated in a pool of major markets, this study recommends that investors approach the international diversification problem using a market segmentation approach, that is, Australia and the US/Australia and the rest of the major markets.

APPENDIX I

Bivariate VAR Lag Order Selection Criteria

Likelihood Ratio Statistics

$$LR = (T - m)\{\log\left|\Omega_{l-1}\right| - \log\left|\Omega_{l}\right|\} \sim c^{2}(k^{2})$$

where:

$\left|\Omega_{l-1}\right|$ and $\left|\Omega_{l}\right|$ are the restricted [(l – 1) lags] and unrestricted (l lags) covariance matrices;

T is the number of observations; and,

m is Sim’s (1980) correction factor used to improve small sample properties which equals the number of variables in each unrestricted equation.

Lag	Australia & France	Australia & Germany	Australia & Japan	Australia & UK	Australia & US
1	21.7020*	18.2471	17.4408*	20.0696*	46.6837*
2	9.1599	10.0797*	0.5618	2.9908	2.7819
3	6.5513	2.0465	1.4322	2.9482	2.8998
4	4.1804	4.3848	8.6063	4.7005	2.4877
5	1.2111	0.7953	2.6847	1.8746	0.8041
6	3.8820	7.4905	7.8063	5.3682	8.8283
7	2.2603	4.3166	4.4738	6.7631	7.8963
8	3.1846	4.5228	1.5410	0.4702	2.6483
9	2.2948	1.4909	6.0742	3.9038	2.3503
10	5.7990	2.0355	5.9257	3.4977	0.2764

* Indicates lag order selected by the sequential modified LR test statistic (each test at 5% level).

APPENDIX II

Johansen Cointegration Test Summary

The earlier tests were specified according to 'Case 2'. The results from 'Case 1' and 'Case 5' could be largely ignored because the specifications were not consistent with the data. Therefore, in comparing 'Case 2' with 'Case 3 and 4', it can be seen that the final results were relatively insensitive to the inclusion of deterministic trends. The trace and max-eigenvalue statistics gave conflicting results when the trends were included. This offered some support for the test specification that was used.

Case:	1	2	3	4	5
Data Trend:	None	None	Linear	Linear	Quadratic
Rank or No. of	No Intercept	Intercept	Intercept	Intercept	Intercept
Cointegrating Equations	No Trend	No Trend	No Trend	Trend	Trend
Selected (5% level) Number of Cointegrating Relations by Model (columns)					
Panel A: Australia & France (1 lag)					
Trace	0	0	0	0	1
Max-Eig	0	0	0	1	1
Panel B: Australia & Germany (2 lags)					
Trace	0	0	0	0	2
Max-Eig	0	0	1	1	2
Panel C: Australia & Japan (1 lag)					
Trace	0	0	0	0	2
Max-Eig	0	0	0	1	2
Panel D: Australia & UK (1 lag)					
Trace	1	0	0	0	1
Max-Eig	0	0	0	1	1
Panel E: Australia & US (1 lag)					
Trace	0	1	1	1	1
Max-Eig	0	1	1	1	1
Panel F: Multivariate VAR (1 lag)					
Trace	1	0	0	0	1
Max-Eig	1	0	0	0	0

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